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(54) HIGH STRENGTH OPTICAL WAVEGUIDE

(71) We, INTERNATIONAL STANDARD ELECTRIC CORPORATION, a Corporation organised and existing under the Laws of the State of Delaware, United States of America, of 320 Park Avenue, New York 22, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The use of optical fibres for carrying information is finding increasing application in all fields of communication. The light weight and large information capacity of glass along with its immunity to electromagnetic interference provides an optimum transmission medium. One of the problems involved with the use of glass optical fibres within long lengths of optical cables, however, is its susceptibility to breaking under sudden and prolonged mechanical stress. Although glass is exceptionally strong in tension having theoretical tensile strengths equivalent to a few million pounds per square inch, optical fibres to date break in some instances when tension is applied in the order of a few thousand pounds per square inch.

According to the present invention there is provided a method of forming a high-strength fibre, including the steps of providing a source of heat-softened glass, filtering a gas to remove dust particles therefrom and supplying the filtered gas to a region surrounding the heat-softened glass so as to provide a substantially dust-free atmosphere, drawing the heat-softened glass into a fibre while it is within the region to which the filtered gas is supplied, and coating the dust-free fibre so produced with a protective layer to prevent the deposition of dust on the glass surface.

Glass optical fibres are generally formed from a glass preform containing various core and cladding materials in a solid configuration. The preform is generally formed on a rotating glass working machine such as a horizontal lathe, and is removed from the lathe for drawing into a fibre in a separate operation. The preform after forming into a solid configuration on the lathe is chemically cleaned, rinsed, and carefully handled to avoid interfering with the cleanliness of the glass surface. The glass preform when mounted in a fibre drawing apparatus is then heated to its softening point and continuously pulled into a fibre while the fibre is continuously wound on a rotating drum. Fibre manufactured in this manner when tested for strength exhibited tensile strength measured as high as a few thousand psi (pounds per square inch). Incorporating an inline liquid plastics coating technique to coat the fibre after drawing and before winding on the takeup drum results in fibres having tensile strengths as high as several hundred thousand psi.

In attempting to bridge the large gap existing between the theoretical 3—5 million psi tensile strength of silica, and the relatively low tensile strength of glass optical fibres the glass failure mechanism was investigated and found to be caused by formation of flaws on the fibre surface. Although the actual stress applied to the fibre was of the order of a few thousand psi it was theoretically determined that the effective stress on the glass fibre at the apex of the hairline crack could result in a force equivalence of a few million psi. Examining the cross-section of the fracture under high optical magnification the fibre immediately subjacent the micro-crack formation on the surface revealed that the crack extended in a pie-shape configuration to the vicinity of the fibre centre. The external structure of the crack at the surface revealed that the presence of a foreign material formed the nucleus of the crack formation.

A further investigation revealed that airborne dust particles contacting and settling on the surface of freshly drawn fibre surfaces in some manner cause the fibre to become abraded at the point of contact resulting in eventual micro-crack formation.

The use of an inline liquid plastics coating applicator immediately after drawing the optical fibre substantially increased the ten-

sile strength of the fibre from a few thousand psi up to as high as 800,000 psi. The use of the plastics coating over the exposed fibre surface is believed to protect the fibre surface from contact by airborne dust particles after the fibre drawing operation and from abrasion on hard surfaces during fabrication.

We have found that high strength glass optical fibres may be produced by carefully controlling the surrounding atmosphere during the fibre drawing process. Apparatus and procedures are utilized to remove dust particles from the vicinity of the glass fibre during the fibre drawing process.

To this end the vicinity of the glass from the point where the glass is heated to its softening temperature to the point where the drawn fibre is completely coated with a protective plastics covering is shrouded in a gas-tight housing to keep foreign airborne particles from contacting the exposed fibre surface. Oxygen-containing gases are continuously flushed through the housing enclosing the exposed fibre at one end and exhausted at another to assure a continuous clean, dust-free ambient surrounding the exposed fibre. Submicron filters are used to ensure that the incoming flushing gas is free from dust particles and an electrostatic eliminator is positioned within the housing coextensive with the drawn fibre to neutralize the electrostatic charges that build up on the air borne particles and fibre surfaces, and hence preventing the fibre from attracting these particles.

The drawing of the glass fibres within a controlled dust-free ambient prevents, or at least minimises the incidence of the formation of flaws on the glass surface.

There follows a description of a preferred embodiment of the present invention. This description refers to the accompanying drawings, in which:—

Figure 1 is a front sectional view of the fibre drawing apparatus of this invention; and

Figure 2 is a cross-section of a finished optical fibre manufactured by the apparatus of Fig. 1.

In order to manufacture optical fibres having tensile strengths approaching the theoretical maxima of 3—5 million psi the fibre drawing apparatus described in Fig. 1 was assembled.

The fibre preform 10 is inserted in a clamping mechanism 11 and heated to its softening temperature by a suitable source of heat 15. The resulting drawn fibre 16 is enclosed within a housing 12 which has an intake 13 for receiving a filtered source of air or alternate source of oxygen which passes by the fibre 16 and exits from the housing 12 at the exhaust orifice 14.

The housing 12 can be made of any suitable material which should be transparent so that the operator can continuously observe the fibre drawing process. The heat source 15 can be, for example, an oxygen-hydrogen flame but could also consist of a laser or a radio frequency coil. The purpose of the housing 12 is to prevent any dust particles from contacting the fibre 16 at any time during the fibre drawing operation. The filtered oxygen-containing gases introduced into the intake 13 provide the proper chemican ambient for the correct fibre chemistry, and in flowing over the fibre surface, ensure that any dust particles will not accidentally reach the fibre surface.

To provide added assurance that should any dust particles enter the housing 12 they would not become electrostatically attracted to the fibre 16 an electrostatic eliminator 26 is provided within the housing 12 coextensive with the fibre 16. The electrostatic eliminator 26 provides a continuous neutralization of any dust particles present in the gas stream, and thus eliminates any electrostatic attraction of the dust particles by the drawn fibre.

Once the fibre 16 has been drawn in the dust free environment provided within housing 12, the fibre 16 is then drawn through a first plastics material 17 within a dip coater 18. The purpose of the plastics material 17 is two-fold, namely, first to cover the exposed fibre surface and thereby prevent any dust particles external to the housing 12 from contacting the surface of the fibre 16; and to provide a soft, flexible and resilient covering to the fibre surface. The additional function of the soft plastics coating 21 will be described in greater detail below. In order to prevent excess plastics 17 from leaking out of the dip coater 18 a concentric seal 20 is provided in the orifice 19 through which the fibre is drawn during the coating process.

A second plastics material 22 is extruded over the first soft plastics coating 21 by means of the extruder 23 and provides a hard plastics coat 24. After the hard plastics coat 24 has been applied the fibre is wound upon the takeup reel 25 upon which it is stored. A second electrostatic eliminator 27 is positioned in the vicinity of takeup reel 25 in order to prevent the accumulation of an electrostatic charge on the surface of the coated fibre during the fibre winding operation.

The purpose of the combination outer hard plastics coating 24 and the inner soft plastics layer 21 can be seen by referring to Figure 2. Here the finished coated fibre 28 consists of a high refractive index core 30 surrounded by a lower refractive index material 29. For the purpose of this description only, the core 30 could consist of a germania silicate glass, while the cladding 29 could consist of a borosilicate glass or pure

silica. In some applications, however, a pure silica core 30 is employed and the soft plastics protective layer 21 is chosen of material having suitable transmissive and refractive properties to provide a soft protective layer and to provide the optical cladding for the silica core 30. In this configuration the intermediate cladding layer 29 is not employed. The outer hard plastics coating 24, usually of a material similar to Teflon (Registered Trade Mark) is extruded over the soft plastics protective layer 21 which can, for example, consist of a silicone resin. This combination of the soft protective layer 21 and the hard coating 24 provides a high strength fibre resistant to breaking when the fibre is wound in a tightly coiled configuration. The soft plastics layer 21 provides a cushion effect when the fibre is subjected to forces resulting from winding the fibre in a tight bending radius.

Fibres manufactured by the aforementioned process can exhibit tensile strengths as high as 2—3 million psi.

Although the preferred embodiment is directed to methods and apparatus for producing high strength optical waveguides this is by way of example only. The invention finds application wherever high strength glass fibres may be required.

Examples of materials from which the outer coating can be made include per fluoroalkoxy materials, a fluoro ethylene propylene material, and an elastomeric polyester.

WHAT WE CLAIM IS:—

1. A method of forming a high-strength fibre, including the steps of providing a source of heat-softened glass, filtering a gas to remove dust particles therefrom and supplying the filtered gas to a region surrounding the heat-softened glass so as to provide a substantially dust-free atmosphere, drawing the heat-softened glass into a fibre while it is within the region to which the filtered gas is supplied, and coating the dust-free fibre so produced with a protective layer to prevent the deposition of dust on the glass surface.

2. A method as claimed in claim 1, wherein the source of heat-softened glass is an optical fibre preform.

3. A method as claimed in claim 1 or 2, further including the step of subjecting the filtered gas in said region to an electrostatic eliminator to remove any electric charges from the fibre surface and any dust particles not removed by the filtration.

4. A method as claimed in claim 1, 2, or 3, wherein the protective layer is made of a plastics material.

5. A method as claimed in claim 1, 2, or 3, wherein the protective layer is made of an elastomeric material.

6. A method as claimed in claim 5, wherein the elastomeric material is a silicone resin.

7. A method as claimed in any preceding claim, including the step of providing an additional layer over the protective layer.

8. A method as claimed in claim 7, wherein the additional layer is made of a plastics material.

9. A method as claimed in claim 8, wherein the material of the additional layer is a per fluoroalkoxy (PFA) material, a fluoro ethylene propylene (FEP) material, or an elastomeric polyester.

10. A method of making a high strength fibre substantially as hereinbefore described with reference to the accompanying drawings.

11. Apparatus for making a high strength fibre by the method of any one of claims 1 to 10.

12. A high strength fibre made by the method or apparatus as claimed in any preceding claim.

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Fig.1.

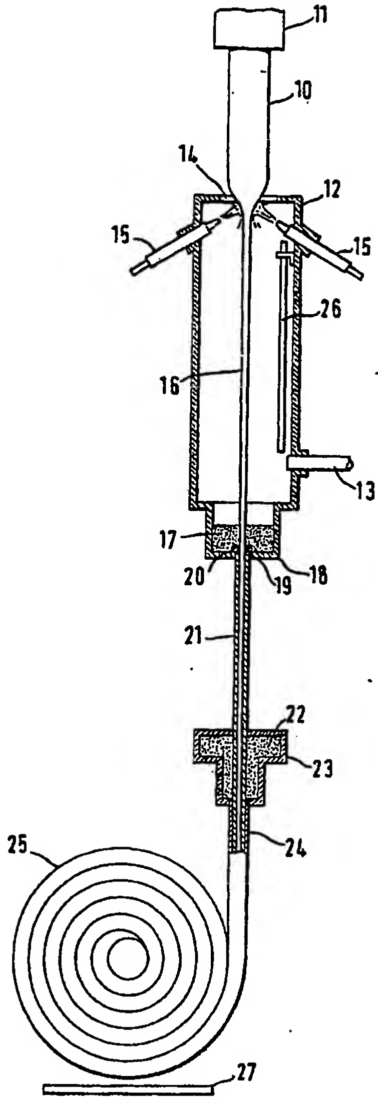
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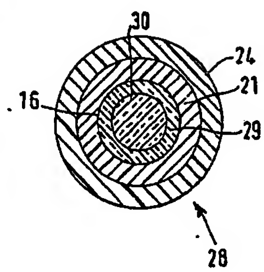
Fig.2.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